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Procedural Memory in Children with Autism: Double Dissociation?

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ABSTRACT

Autism, which involves persistent deficits in social communication and behavioral flexibility, has been increasingly prevalent in recent years. Although considerable research on language in autism has focused on pragmatic impairments, few researchers have attempted to identify the link between memory and language impairments. Walenski, Tager-Flusberg, and Ullman (2006) hypothesized that procedural memory deficit leads to grammatical impairments. Due to dearth of studies examining procedural memory across varied output modalities, the present investigation was planned. Thus, the main aim of this study was to investigate procedural memory across phonological and orthographic domains in children with autism.

Ten children with high-functioning autism aged from 7 -17 years and typical controls were recruited as participants in the present study. Test for Examining Expressive Morphology (Shipley, Stone & Sue, 1983), consisting of true words, was used to investigate whether intact declarative memory takes over the function in the clinical group by correctly inflecting the target word verbally. In addition, Wug Test (Berko, 1958) was administered to examine non-word inflections in both clinical and control groups. Sentence-completion tasks for both spoken and written modalities were administered to individual participants in a sound-treated room.

The findings of the the present study indicate that the clinical group obtained good scores on true word verbal tasks since they stored the word with suffixes as a whole unit in their relatively spared declarative memory. However, since non-words are not stored in declarative memory, verbal performance of the clinical group on Wug Test was found to be impaired.

Statistical analysis revealed no significant difference between the two groups on non-word tasks in orthographic modality. This suggests that orthographic procedural memory is spared although the phonological counterpart is impaired in children with autism. Thus, double dissociation of written and spoken language processes in procedural memory is hypothesized.

The potential implication of the present study is that procedural memory training using intact orthographic modality could enhance learning of morphological rules in children with autism. However, future studies on larger sample size across the spectrum is recommended to establish clinical implications.

KEYWORDS: *Procedural memory, declarative memory, autism, double dissociation*

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INTRODUCTION

Autism, which involves persistent deficits in social communication and behavioral flexibility, has been increasingly prevalent in recent years. Children with autism are characterised by a range of linguistic deficits. Eigisti et al. (2007) found that children with autism have less well-developed morpho syntactic skills than younger typically-developing children. Evidence suggests that grammar and pragmatics are impaired in autism while lexical knowledge is relatively spared (Walenski, Tager-Flusberg, & Ullman, 2006). Although considerable research on language in autism has focused on the type of linguistic impairments, few researchers have attempted to identify the link between memory/learning systems and language.

Paradis (2004) and Ullman (2004) distinguish between procedural and declarative memory, also known as implicit/non-declarative and explicit memory, respectively. These two long-term memory systems in the brain interact in learning and processing. Procedural memory, which involves unconscious recollection of how to perform a task or procedure, is acquired incidentally with extended practice and used automatically. Declarative memory, which encompasses consciously acquired knowledge about words,

facts and events is learned consciously, rapidly and is consciously controlled when used.

Specifically, Ullman (2001, 2004) argued that procedural memory sustains rule-governed sequential combination of units (grammar and phonology), while semantic memory, which is a type of declarative memory, sustains the lexicon or word forms and meanings. Semantic memory is posited to remain largely intact in children with autism. Evidence suggests that gene *FOXP2* and neurotransmitter dopamine underlies functioning of procedural memory system (Ullman, 2005) which is affected in children with morpho-syntactic impairment.

Walenski, Tager-Flusberg, and Ullman (2006) subsequently hypothesized in the 'Procedural Deficit Hypothesis' that procedural memory deficit leads to grammatical morphology impairments in children with autism. This causes difficulty in creating words with affixes on the basis of grammatical rule. It was posited those children with autism learn these words as whole lexical units using their intact declarative memory to compensate for impaired procedural memory. This was explained by Ullman and Pullman (2015) in their 'dual-systems' model of language acquisition, as the 'See-Saw effect'. For instance, instead of applying the rule of adding plural marker to noun, i.e., 'book' + '-s', they retrieve 'books' as a single whole unit from their declarative memory, where it is learned and stored on previous linguistic exposure.

Furthermore, the Procedural Deficit Hypothesis suggests that children with autism would perform well on grammatical morphology tasks involving true words since intact declarative memory takes over the function. Tasks involving non-words, which are not stored in declarative memory, permit to examine the procedural memory system solely without any intrusion from declarative memory. Therefore, Bartolucci and Albers (1974) suggested the use of a non-word task such as the Wug Test (Berko, 1958), to examine procedural memory. A recent study by Boucher and Anns (2018) alternatively proposed a four-system model of learning in which intact semantic and procedural memory are used to compensate for weaknesses in episodic memory and perceptual learning. They argued that this can better explain patterns of language ability across the autistic spectrum Due to dearth of studies examining procedural memory across spoken and written output modalities, the present investigation was planned on the basis of 'dual-systems' model.

Aim of the study

The main objective of this study was to explore whether procedural memory is impaired for both phonological and orthographic domains in high-functioning children with autism. The current investigation aimed:

1. To investigate whether there is a significant difference between high-functioning children with autism as compared to typically developing children on non-word verbal and written grammatical morphology tasks.
2. To investigate whether there was significant difference between the two groups on true-word verbal and written grammatical morphology tasks.

Method

Participants

A total of 20 children were recruited as participants in this study. Ten children with high-functioning autism spectrum disorder aged from 7-17 years (Mean age: 10.8 years) and ten typically developing individuals constituted the clinical and control group, respectively.

Inclusion Criteria for Clinical Group

The participants of the clinical group were diagnosed as having Autism Spectrum Disorder (ASD) according to ICD-10 criteria. Since they had relatively good verbal skills, Childhood Autism Rating Scale, Second Edition High-Functioning version (CARS2-HF, Schopler, Van Bourgondien, Wellman & Love, 2010) was administered. The clinical group received high-ratings (score of 3) on the following items: Social-Emotional Understanding, Emotional Expression and Regulation of Emotions, and Relating to People, suggestive of High-Functioning Autism (HFA).

Most of the participants were on speech-language intervention services at AsterKIND (Kids Integrated Neurodevelopmental Centre), Aster Centre of Excellence in Child and Adolescent Health, Aster Medcity hospital and few were enrolled from private Speech-Language Pathology clinics in Ernakulam, Kerala. The participants were recruited over a period of 18 months and three participants were also receiving occupational therapy at Aster KIND in addition. The term 'autism' is alternatively used in this study to refer to ASD or HFA.

Inclusion criteria was: 1. English was the primary language spoken at home, 2. verbal and written repertoire of around four to five word utterances, 3. vocal imitation: level-4 or 5 on Behavioral Language Assessment form (Sundberg & Partington, 1998), 3. Receptive language age of more than 6 years and expressive language age of atleast 4 to 4.6 years on Comprehensive Language Assessment Tool for children (CLAT, Navitha & Shyamala, 2012) 4. able to perform sentence completion tasks both verbally and through writing, 5. joint attention, sitting tolerance and compliance emerging well, 5. no auditory, visual, cognitive or motor deficits co-morbid with autism.

All the participants obtained a minimum score of 23 on the Auditory Filtering subtest of Short Sensory Profile (SSP, Dunn, 1999) and in addition, Auditory Retrieval subtest of Manipal Manual for Cognitive Linguistic Abilities (Mathew, Bhat, Sreya, & Arora, 2013) was used to rule out auditory processing difficulties.

Inclusion criteria for Control Group

Language age- and gender-matched typically developing individuals constituted the control group. They were screened with ten-point disability check (Singhi, Kumar, Malhi& Kumar, 2007) to rule out associated deficits. The individuals had good written and spoken expression in English, as it was the primary language spoken at home, although their parents were native Malayalam speakers. The control group had normal hearing, intelligence, sensory and motor skills.

Procedure

In order to investigate the See-Saw effect, the Test for Examining Expressive Morphology (Shipley, Stone & Sue, 1983) was used. It consisted of true words and was used to investigate whether intact declarative memory takes over the function in the clinical group by correctly inflecting the target word verbally. In addition, Wug Test (Berko, 1958) was administered to examine non-word inflections in both clinical and control groups. Picture stimuli of TEEM (Shipley, Stone & Sue, 1983) and Wug test (Berko, 1958) were presented along with the written or verbal sentence to elicit

the target response. This task aimed to examine whether procedural memory was intact or not.

Each picture stimulus was presented with the target sentence and the participants were instructed to correctly inflect the target words verbally and through writing suffixes to true or non-words. This study implemented sentence-completion tasks administered to individual participants in a sound-treated room. They received practice trials before starting the task to ensure that they understood the instructions.

Appropriate use of suffix was considered as correct response and scored as '1'. Omission of suffix or any incorrect response was given a score of '0'. For example, after presenting the following visual stimuli with the sentences, participant was instructed to complete the target sentence 'There are two__' with correctly inflected word 'Wugs' by saying it aloud and writing the inflected word. A sample stimulus of the Wug test is shown in Figure 1.

Figure 1Sample Wug test stimulus

Results and Discussion

In order to examine differences in test scores between the control and clinical groups, an independent sample t-test was conducted. Results indicated that there was no statistically significant difference ($p>0.05$) between the clinical and control group on the true-word task for both phonological and orthographic output modalities (see Table 1).

Although children with high-functioning autism performed well on true word tasks similar to the controls, it is proposed that they devised a different route to learn, store, and use words affixed with grammatical morphemes. In line with previous findings, this supports the Procedural Deficit Hypothesis (Walenski, Tager-Flusberg, & Ullman, 2006) that impaired procedural memory is compensated by intact declarative memory in autism. This finding also derives corroborative evidence from our previous research on procedural memory in Malayalam speaking children with autism (Treasa et al., 2014).

Table 1 Phonological and orthographic means for clinical and control group on TEEM

	Group			
	Clinical	Control	t	df
Phonological	75.9 (5.95)	82.4 (10.76)	-1.671	14.035
Orthographic	67.6 (5.87)	71.4 (6.02)	-1.429	17.989

Note: Standard deviations appear in parentheses below means.

While typically developing children learned rule-governed grammatical computations to form words using intact procedural memory, children with autism bypassed grammatical processing and stored the word with suffixes as a whole unit in their relatively spared declarative memory. This supports the 'See-Saw effect' which was proposed by Ullman and Pullman (2015).

Furthermore, children with autism (see Figure 2) performed well on present progressive, regular plural, possessive, regular past tense sub-tests than the other morphemes such as third person singular, irregular plurals, regular comparatives/superlatives, irregular past tense and irregular comparatives or superlatives. This is similar to the ranking of acquisition of morphemes as delineated by Brown (1973)'s stages of morphology. It is proposed that children with autism acquire language at a slower rate but in a similar order of emergence of morphemes as compared to the typically developing children.

Figure 2 Overall means for clinical and control group for specific morphemes

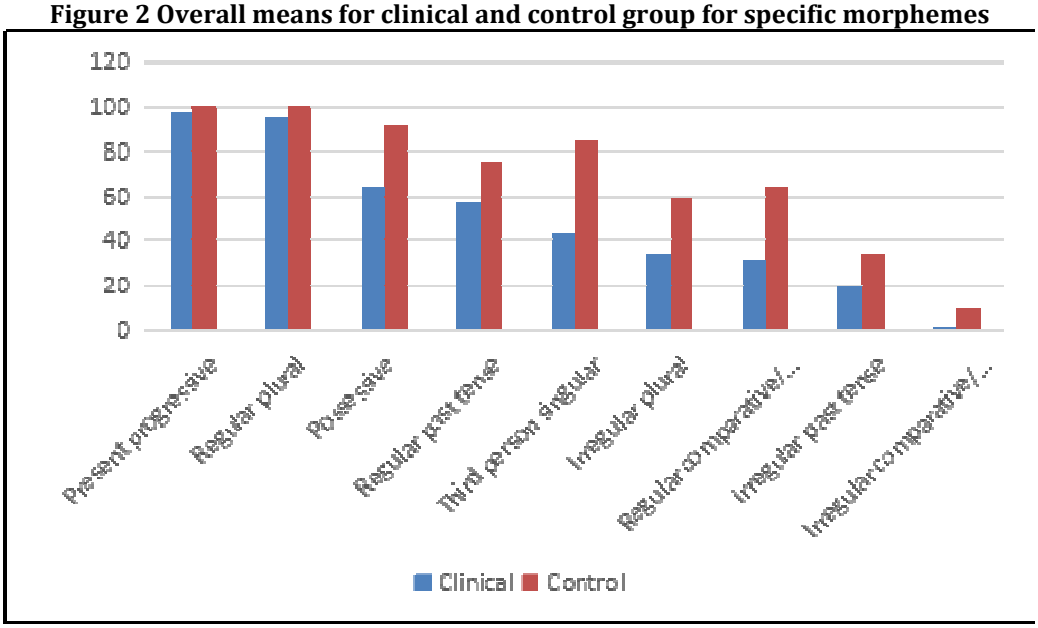

Table 2 Phonological and orthographic means for clinical and control group on Wug test

	Group			
	Clinical	Control	t	df
Phonological	47.4 (8.98)	71.3 (7.06)	-6.616***	17.043
Orthographic	67.7 (4.79)	73.0 (7.02)	-1.972	15.874

Note: *** = p ≤ .001. Standard deviations appear in parentheses below means.

Since non-words are not stored in declarative memory and the ability to learn sequences and rules in morphosyntax is impaired in autism, performance of the clinical group on Wug Test in the phonologic output modality was found to be significantly lower ($p<0.001$) than the control group (Table 2). In contrast, performance of clinical group was comparable to the control group for non-word tasks in the written or orthographic output modality. There was no significant difficulty for clinical and control group in writing suffixes to non-words on the basis of grammatical rules.

This suggests that orthographic procedural memory is spared although the phonological counterpart is impaired in children with autism. Therefore, existence of independent written and spoken language sub-domains under procedural memory is proposed. This could provide more insight into the 'Dual-system' model proposed by Ullman and Pullman (2015) and the four-system model of learning by Boucher and Anns (2018). However, more research is needed to establish link between memory and language in high-functioning autism or across the autism spectrum disorder.

Conclusion

Functional independence of phonological and orthographic domains of procedural memory indicates double dissociation of procedural memory. Hence, these modalities may be affected in isolation as evident in children with autism. Thus, double dissociation of written and spoken language processes in procedural memory is hypothesized. The potential implication of the present study is that procedural memory training using intact orthographic modality could enhance learning of morphological rules in children with autism. However, future studies on larger sample size across the spectrum is recommended to establish clinical implications.

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